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THE PENNSYLVANIA
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IONOSPHERIC RESEARCH

Scientific Report (E) No. 182

AN IMPROVED LOW FREQUENCY SWEEP POLARIMETER

by

S. Weisbrod and A. J. Ferraro

April 1, 1963

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SCIENTIFIC REPORT (E.) No. 182

Ionosphere Research Laboratory

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THE PENNSYLVANIA STATE UNIVERSITY

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ABSTRACT

This report describes an improved version of a low frequency polarimeter which is used in conjunction with the low frequency sweep studies at the Ionosphere Research Laboratory. The purpose of this equipment is to resolve signals received from horizontal cross polarized dipoles into signals which are proportional to the sum and difference of the ordinary and the extraordinary magneto-ionic components over the frequency range of 80 to 1200 kc. In the construction of this equipment much emphasis has been placed on sensitivity, stability, elimination of spurious coupling between channels, and the ease of routine calibration and adjustment.

1. Introduction

During the past two years, in the course of routine low frequency ionosonde soundings at the Ionosphere Research Laboratory, it was noted that there frequently occur, as a function of frequency, systematic reversals in the sense of rotation of the polarization of the downcoming echoes. These have been most frequently observed during the night in the frequency range of 300 to 700 kc.(1) Inasmuch as the polarization of the echoes is fairly sensitive to the fine structure of the E region, a study of these polarization reversals offers a powerful tool for the investigation of electron profile irregularities in the E region. Some theoretical studies along these lines have already been carried out and were reported in the literature.(2,3)

These earlier investigations have been seriously hampered by frequent mal-functioning of the experimental equipment. These caused large gaps in the continuity of the experimental data, and also made the interpretation of the data more difficult. Inasmuch as the data already obtained have convincingly demonstrated the fruitfulness of this approach, it was decided that certain parts of this equipment should be redesigned and rebuilt to improve the quality of future records.

This report describes the new polarization receiver which is the first unit that has been completed. Revisions of the transmitter and the programming units are now under construction and will be described in a later report.

2. Experimental Procedure for Obtaining LF Polarization Data

To facilitate the description of the receiver it will be helpful to summarize the experimental procedure used in securing the polarization data. This will define certain criteria and specifications for the receiver and other experimental equipment.

A 100 kw broadband pulse transmitter sounds the ionosphere 60 times per second with 150 μsec pulses. The carrier frequency of the pulses is progressively varied from 80 to 1200 kc over a period of about two minutes. This cycle is repeated once every 15 minutes. The operation is usually confined to the nighttime hours because of excessively high D region absorption during the daytime hours.

The transmitting antenna consists of a horizontal dipole about 240 ft. above the ground and orientated in a magnetic north-south direction. The receiving antenna consists of two orthogonal horizontal dipoles. The physical separation between the transmitting and the receiving sites is about 2000 ft.

The carrier frequency for the transmitter is derived by mixing a 3 mc crystal oscillator signal with a variable frequency signal of 3.08 to 4.2 mc. This variable frequency signal is also transmitted through a coaxial line to the receiver. Since the front end of the receiver is broadband

and the IF frequency is 3 mc, this simple scheme automatically and precisely tunes the receiver to the transmitter frequency.

The polarization receiver accepts the signals received from the two horizontal cross polarized receiving antennas and processes them in such a manner as to make available output voltages proportional to the following quantities:

a. field strength of the ordinary component

b. field strength of the extraordinary component

c. the difference between the two detected components

d. the sum of the two detected components

In normal operation this difference between the ordinary and the extraordinary component is used as the z-axis modulation for a continuous film scope camera recording. Each cycle of operation, which lasts about two minutes, uses up about two inches of film. If the film is held sideways the "x" axis represents the signal frequency and the y axis represents the virtual height of reflection. The z-axis modulation is so adjusted that the ambient noise level produces gray background on the film and the downcoming echoes cause it to turn either black or white depending on the sense of rotation. Height and frequency markers are inserted automatically by supplementary equipment.

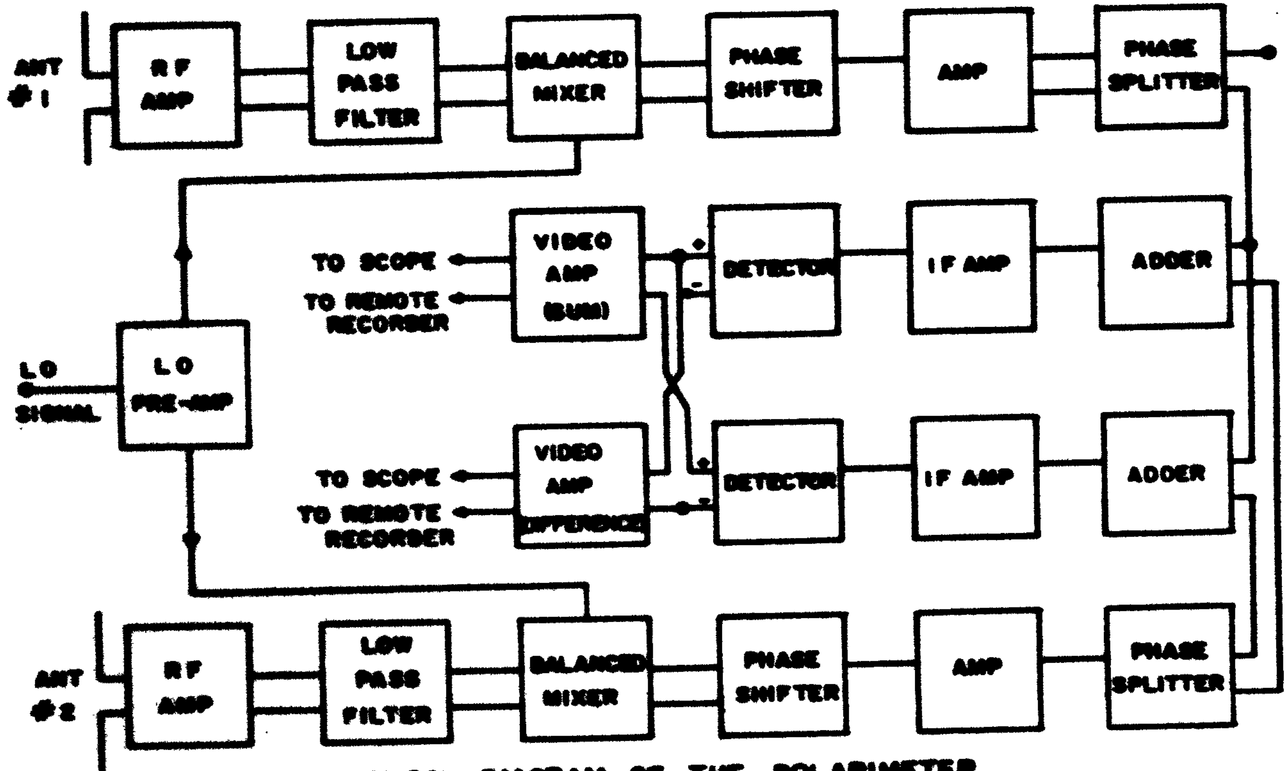
3. Description of the Receiver

The brief outline of the experimental procedure presented in the previous section forms the basis for receiver specifications. Basically the polarization receiver must consist of two identical channels where signals from the two cross-polarised antennas are added and subtracted after undergoing a relative phase change of 90°. The amplified difference of the demodulated outputs of the two channels forms the required z-axis modulation signal.

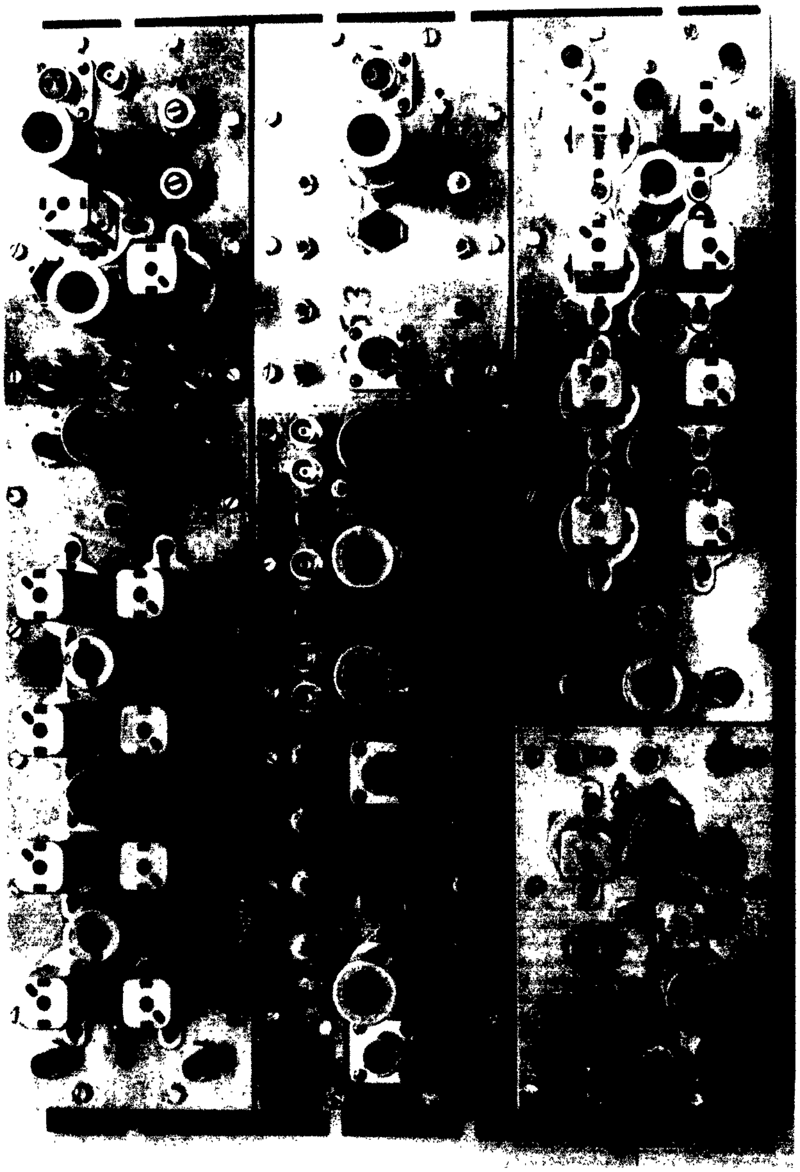
The block diagram of the polarisation receiver is shown in Fig. 1. The two signals from cross-polarised antenna are fed into a broadband RF amplifier whose frequency response is determined by an M-derived low pass filter with a cut-off frequency of 2.0 mc. The RF signals are then heterodyned with the variable frequency oscillator signal cabled from the transmitter. The 3 mc mixer output is first phase shifted to provide the relative phase change of 90°, then amplified and passed through a phase splitting network to provide two out of phase outputs. At this point the two channels are cross-connected to effect addition and subtraction of the two signals and thus reconstruct the two circularly polarised components with opposite sense of rotation.

These two polarization components are next passed through a 3 mc IF amplifier and the detected outputs are then subtracted and added in video amplifiers which furnish the desired z-axis modulation.

Physically the receiver consists of two chassis: the receiver chassis shown in Fig. 2 and the regulated power supply shown in Fig. 13. Referring to Figure 2 it is seen



BLOCK DIAGRAM OF THE POLARIMETER
FIGURE 1



RECEIVER CHASSIS

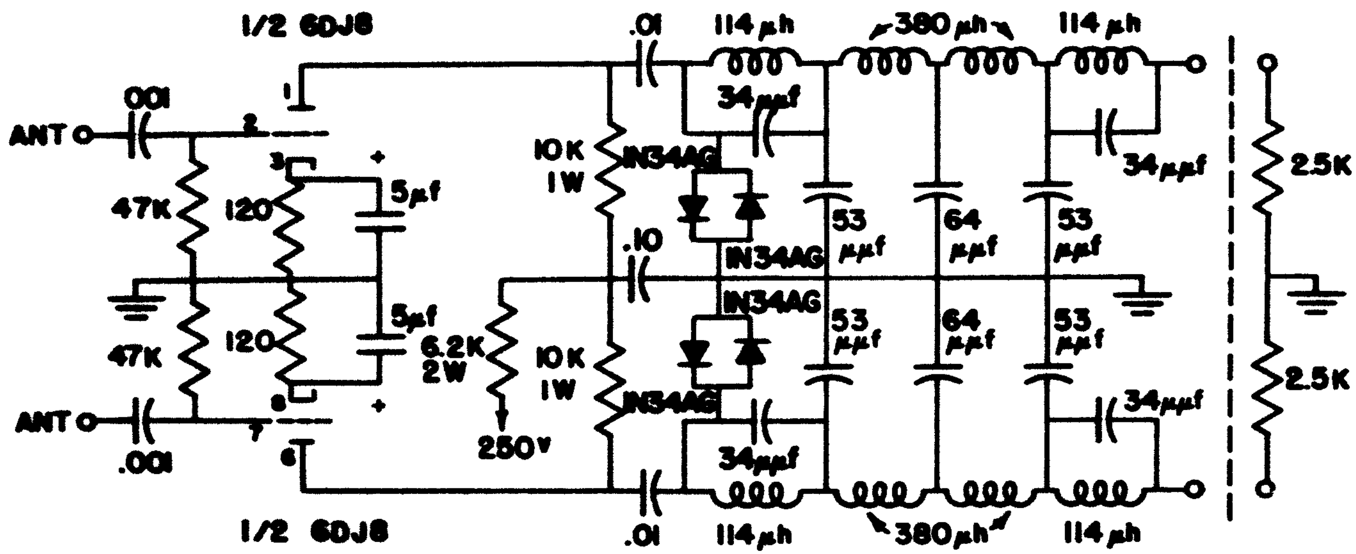
FIGURE 2

that the receiver chassis consists of seven modules. These are: 2 RF amplifiers (each side off center), 2 mixers (top right and bottom left), 2 IF amplifiers (top left and bottom right) and the video amplifier module (center). Each of these units will now be described in more detail.

3.1 RF Amplifier Module

The RF amplifier module, (Figures 3 and 4) houses the RF amplifier and the low pass filter. The RF amplifier consists of a 6DJ8 twin triode amplifier operated push pull, class A_1. The effective shunt impedance of the amplifier matches the low pass filter. The low pass filter consists of two m derived terminating half-sections, (m=.6) joined with two π sections. The cut off frequency is 2.0 mc and the nominal terminating impedance is 2500 ohms. The filter is flat up to about 1300 kc and the overall voltage gain of the RF amplifier, as measured at the far end of the low pass filter, is about 10.

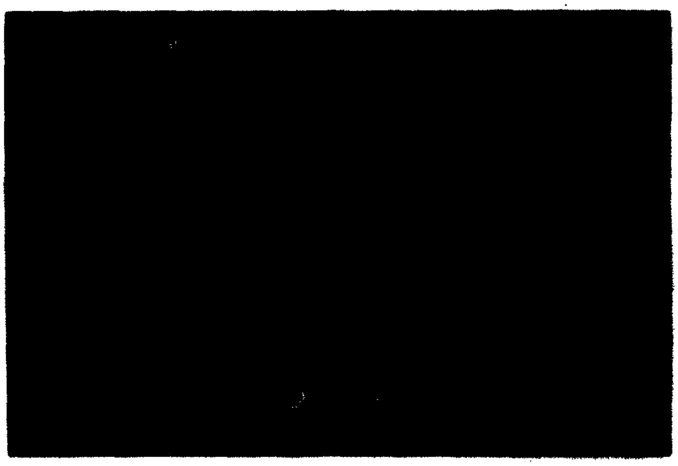
After the receiver was placed into service it was found that the very strong transmitter pulses were causing partial blocking; in spite of short time constants designed into the equipment. This problem was solved by shunting the input into the RF filters by IN34A germanium diodes. At low and moderate signal levels, up to tens of milivolts, the diodes offer very high impedance and for all practical purposes are not in the circuit. The shunting action of the diodes at high signal levels reduced the transmitter



R F AMPLIFIER AND THE LOW PASS FILTER

FIGURE 3

a. TOP



b. BOTTOM

RF AMPLIFIER MODULE

FIGURE 4

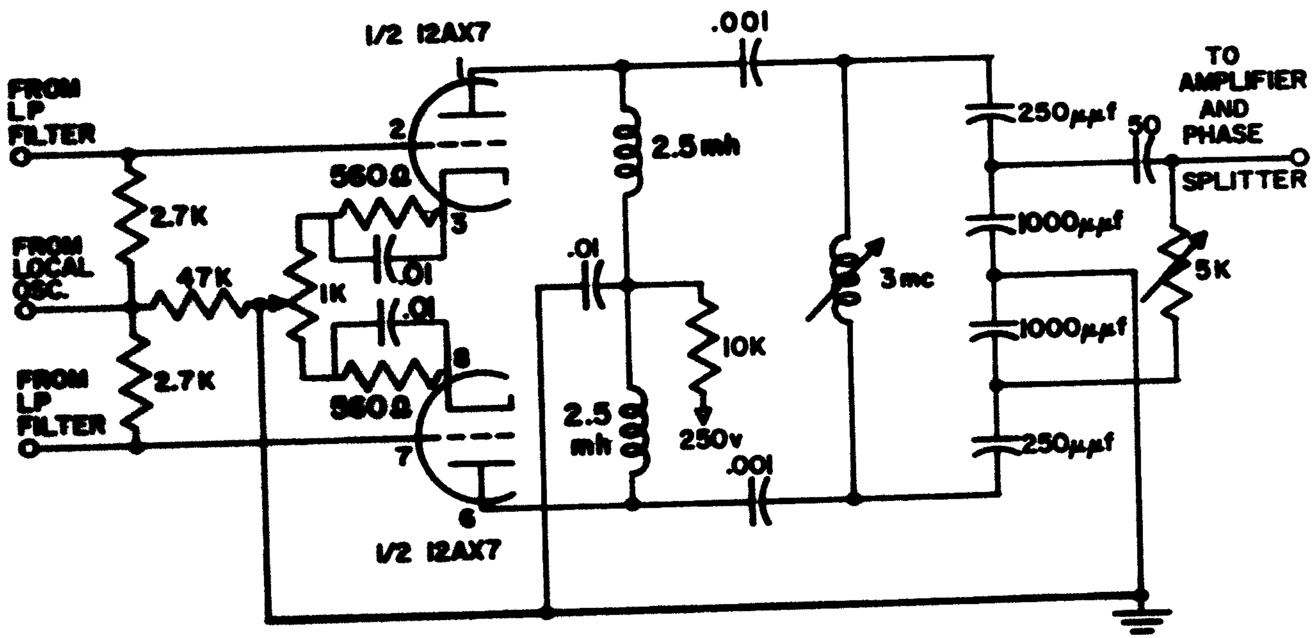
ground pulse from about 70 volts peak-to-peak at the output of the filter to less than 2 volts.

3.2 Mixer Module

The mixer module is comprised of the balanced mixer, phase shifter, amplifier, and a phase splitting network. The schematic of these units and a photograph of the module are shown in Figures 5, 6 and 7. The balanced mixer consists of a 12AX7, the plates of which are choke-condenser coupled into a 3 mc tank circuit. The condenser division of the output provides a low impedance balanced output for the phase shifting network which in turn is coupled into a 12AX7 amplifier. The phase splitting network, which consists of a bifilarly wound toroid transformer, provides low impedance balanced output for subsequent addition and subtraction.

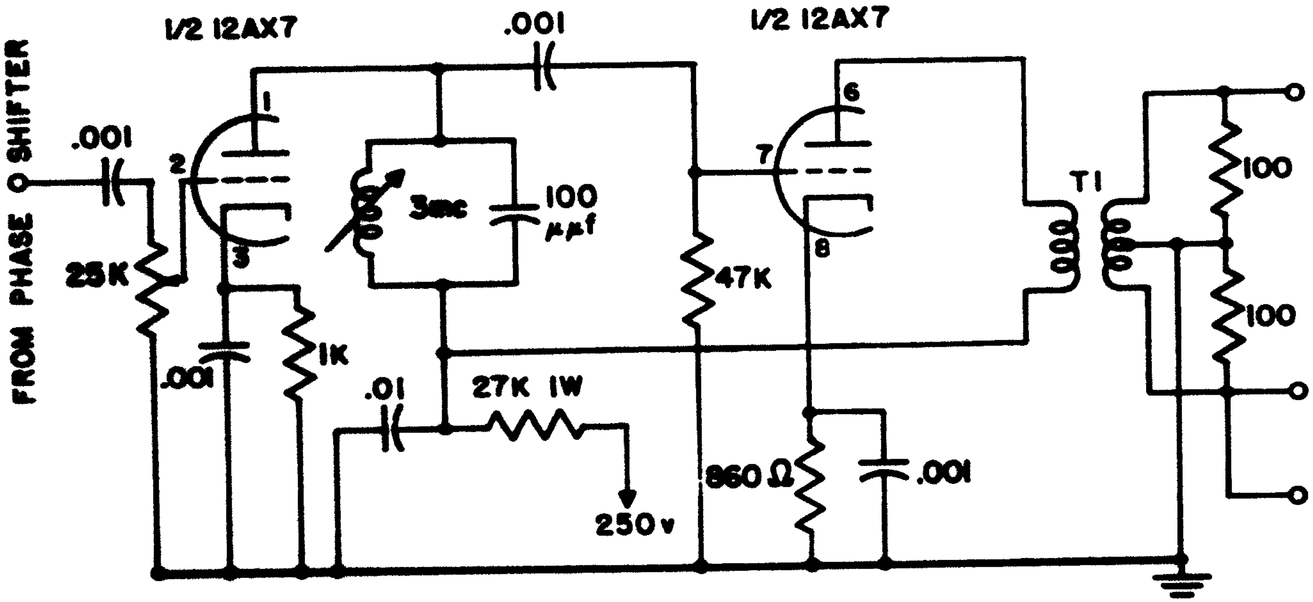
3.3 IF Module

The IF module which contains the adder, the 3 mc IF amplifier and the detector are shown in Figures 8 and 9. The adder network consists of a twin triode 12AX7 where both plates are connected in parallel to a 3 mc tank circuit. As stated earlier the purpose of the adder network is to cross connect the 90° phase shifted signals from the two antennas and thus resolve them into two circularly polarised signals of opposite sense of rotation. The 3 mc/s IF strip serves to amplify and shape the band pass characterisitcs of the receiver. In normal operation the bandwidth is about

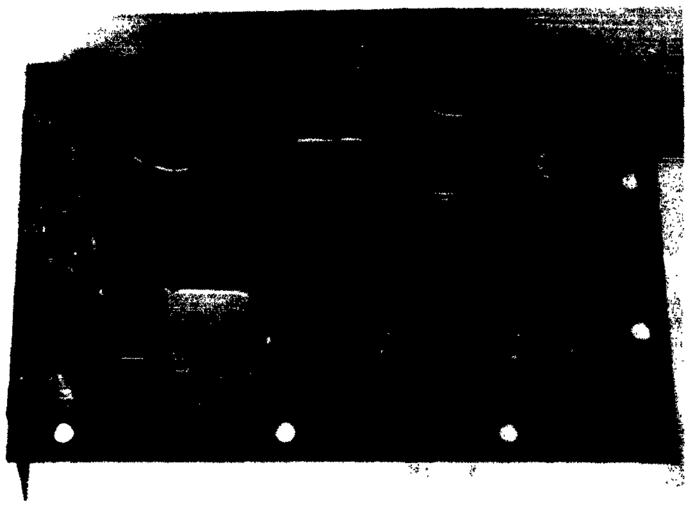


MIXER AND PHASE SHIFTER

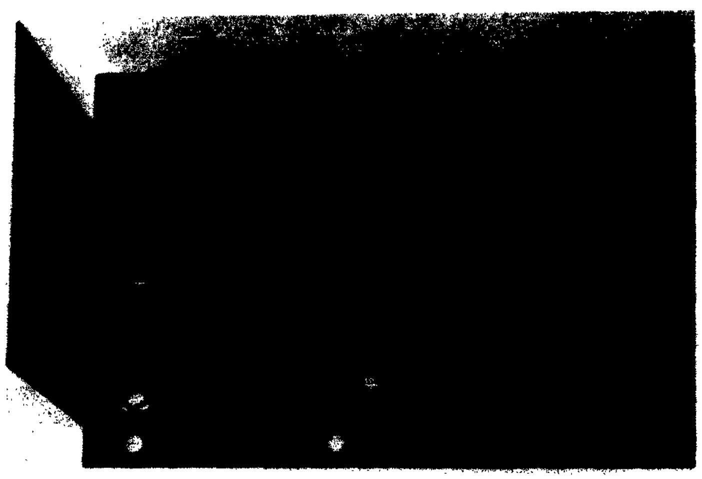
FIGURE 5



AMPLIFIER AND PHASE SPLITTER
FIGURE 6



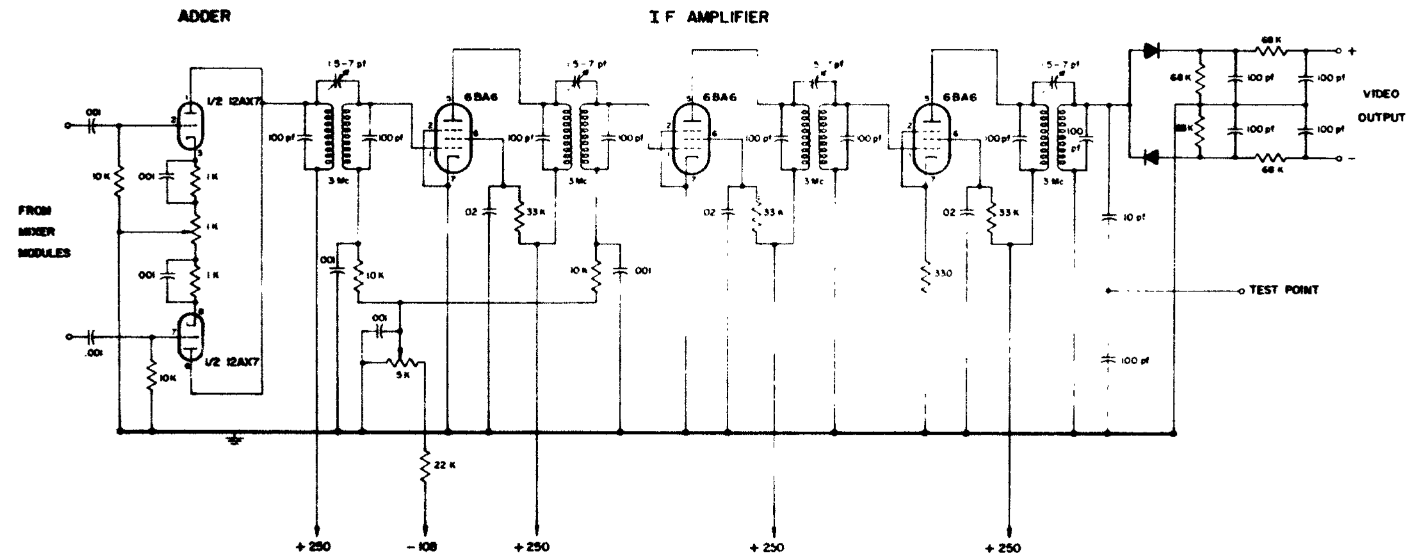
a. TOP



b. BOTTOM

MIXER MODULE

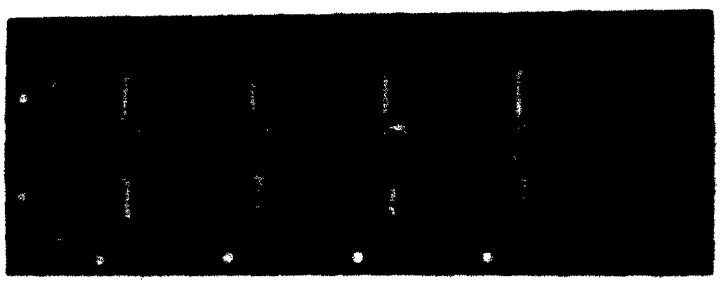
FIGURE 7



ADDER NETWORK, IF AMPLIFIER AND THE DETECTOR

FIGURE 8

a. TOP



b. BOTTOM

IF MODULE

FIGURE 9

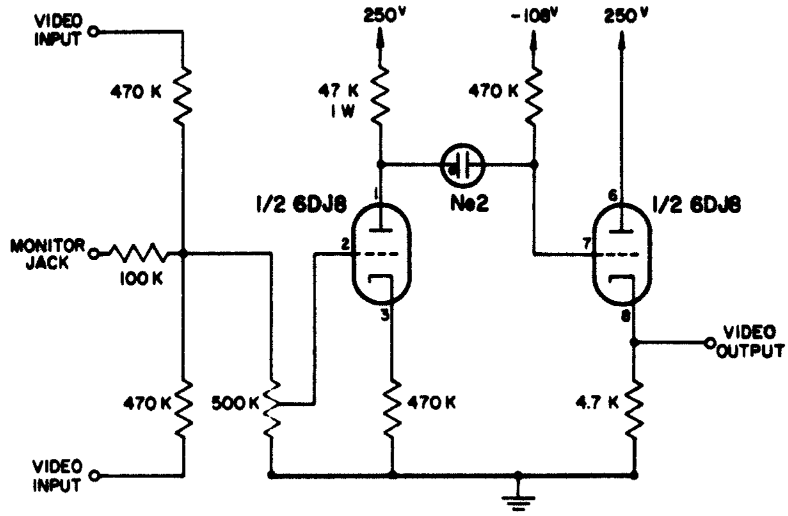
±12 kc and the sensitivity is about 1 μV. The bandwidth may be adjusted by varying the amount of capacitive coupling between the IF stages. The detected signals of either polarity are available at the output of the IF strip. A capacitive divider to a banana jack at the last IF stage is used for tuning and monitoring purposes.

3.4 Video Module

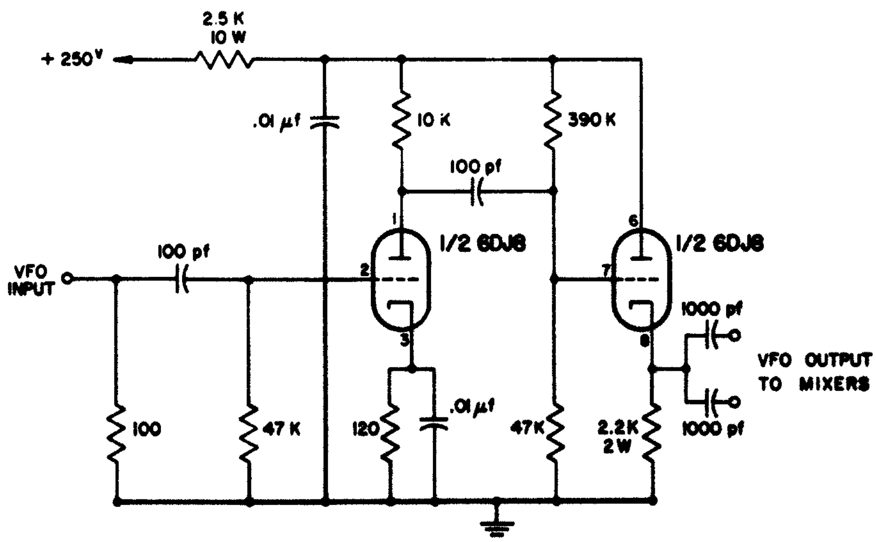
The video module houses two identical video amplifiers and the variable frequency oscillator preamplifier (Figures 10 and 11). The VFO preamplifier raises the level of the injection signal received from the transmitter site to about 10 volts peak to peak as required for proper operation of the mixer. The video amplifier consists of a one stage dc-amplifier cathode-follower combination which provides video signals required for z-axis modulation. One channel is used for the "difference" where the input of opposite polarities is combined and the other channel is the "sum" channel which is used as an auxiliary channel to differentiate between fade-outs and linearly polarized signals.

3.5 Power Supply

Each module has a separate power connection to facilitate servicing. The voltages supplied are 6.3 V ac for filaments, -108V negative for biasing and +250V. Both -108V and 250V are regulated voltages. The detailed circuitry and a photograph of the power supply are shown in Figures 12 and



VIDEO AMPLIFIER



VFO PREAMPLIFIER

VIDEO AMPLIFIER MODULE

FIGURE 10

a. TOP

b. BOTTOM

VIDEO AMPLIFIER MODULE
FIGURE 11

13. The design is of standard feed back type. Either a 5U4 rectifier or solid state diodes may be used interchangebly.

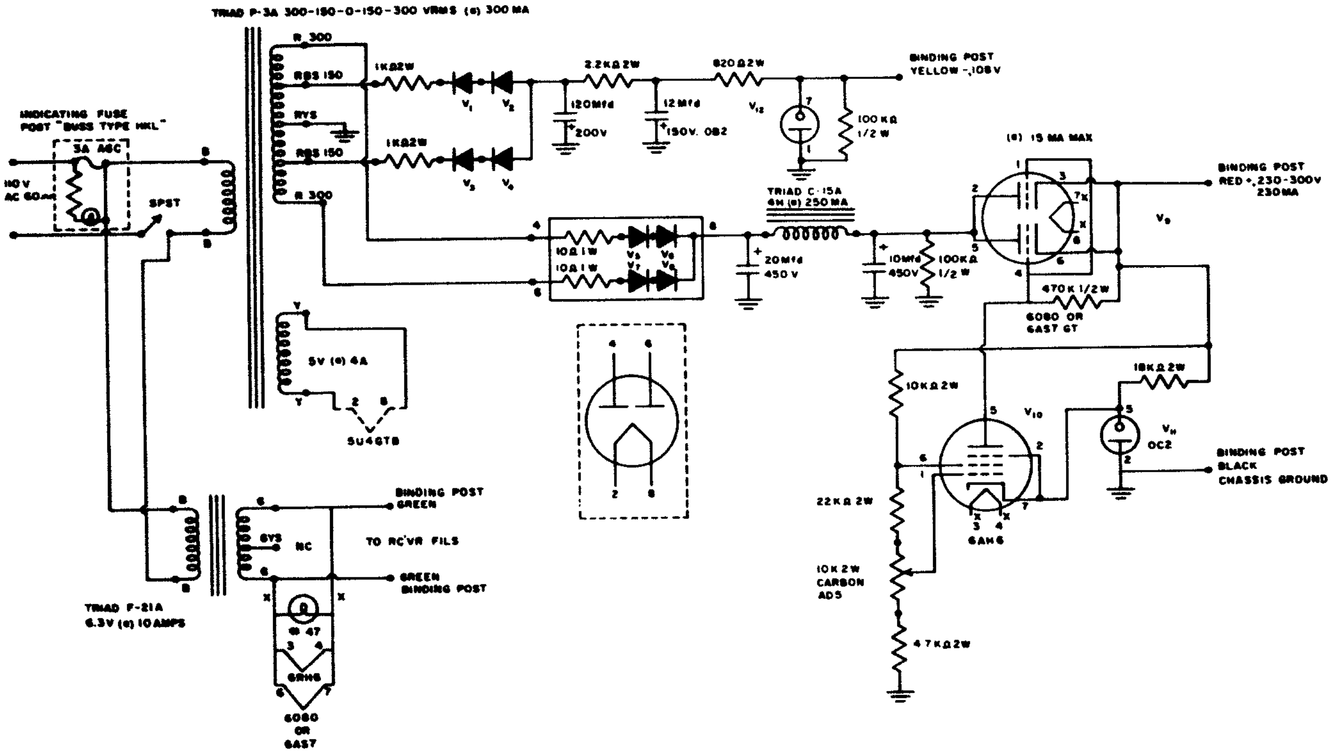
4. Calibration and Alignment Procedures

The calibration and alignment procedures, which are described below, are based on our experience and should prove helpful to anyone who may be faced with the problem of maintenance of this equipment. Inasmuch as the normal operation involves a number of interconnections between the various modules, no adjustments should be attempted without proper equipment and a good understanding of the block diagram of Figure 1. For initial alignment the following equipment should be available.

1. A balanced output signal generator 80 kc to 3000 kc. If balanced output is not available a balun made out of a toroidal transformer may be used.
2. A signal generator 3000 to 4200 kc with a minimum output of 1 volt.
3. A step attenuator with at least 60 db range.
4. A digital frequency counter.
5. A dual channel scope, dc to 3 mc.

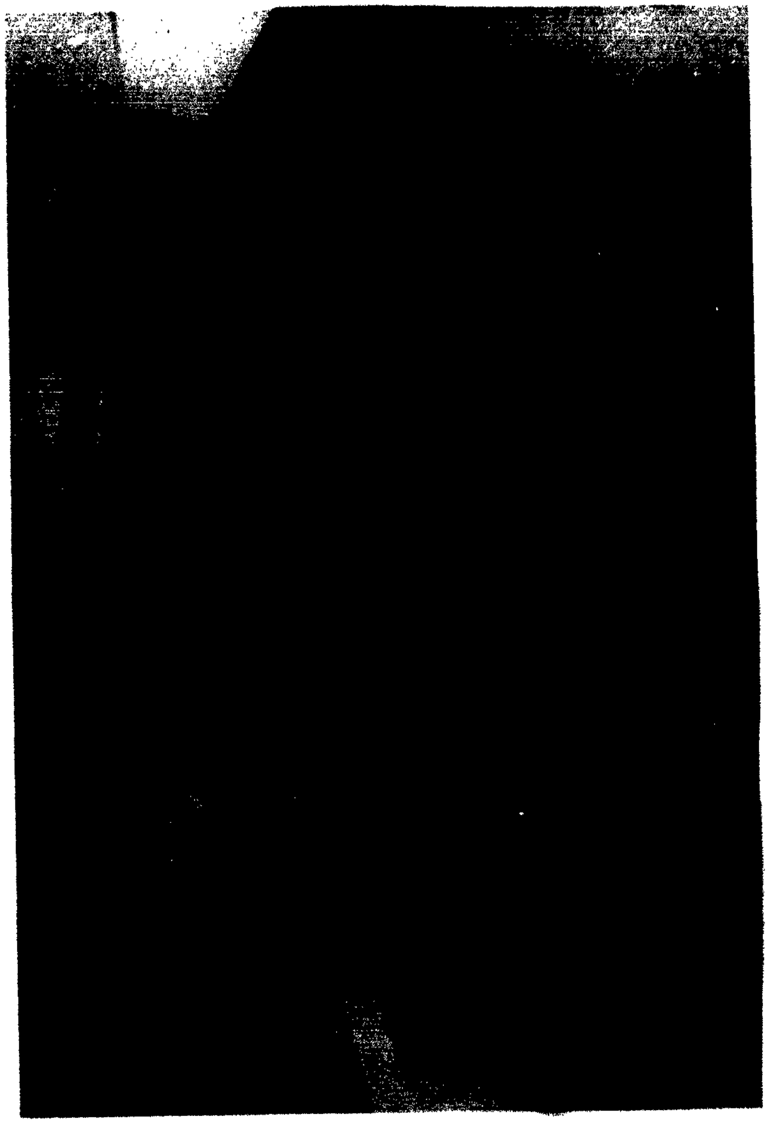
4.1 Alignment of the RF Module

In the alignment of the RF module it is best to first tune up the low pass filter and then select 6DJ8 triodes in



1. V_1-V_8, ALL RECTIFIERS ARE INTERNATIONAL RECTIFIER TYPE 5A4 SILICON
2. ALL CONDENSERS ARE POLARIZED ELECTROLYTICS
3. CIRCUIT IN RED IS AN OPTIONAL ONE FOR USE WHEN THE PLUG-IN SILICON MODULE FAILS: BOTH MATE 8 PIN OCTAL SOCKET.
4. POWER TRANSFORMER IS DERATED TO 250 MA. CONTINOUS BECAUSE CONDENSER INPUT FILTER IS USED.

POWER SUPPLY
FIGURE 12



POWER SUPPLY CHASSIS
FIGURE 13

which both halves of which are well matched. Both RF modules should be worked on at the same time so that point by point comparison will assure as nearly identical performance in both channels as possible. The following procedure will be found useful.

a. remove the RF modules from the receiver.

b. ground the auxiliary filter terminating resistors which will be found ungrounded at the output terminals of the filter.

c. referring to the schematic in Figure 3, open the connections between the 114 and the 380 µh coils, ground the input, the output, and the junction of the two 380 µh coils and thus form two sets of parallel resonant circuits; 114 µh-34 µµf with resonant frequency of 2.55 mc and 380 µh-53 µµf with the resonant frequency of 1.12 mc. Using a 100 k series resistor peak each of these parallel resonant circuits on both modules making allowances for the scope probe. (With a 14 µµf probe the two frequencies are lowered to 2.12 and 1.00 mc; respectively).

d. after completing the above adjustments, check the 6DJ8 triodes for symmetry and run the frequency response of grid input voltage vs filter output voltage. If properly adjusted, the phase and amplitude response of each section of the two filters will be identical up to at least 1300 kc and the amplitude response will remain flat within one db. The overall amplitude gain will be about 10.

4.2 Alignment of the IF Module

To align the IF module connect the 3 mc signal generator to three places: external sync on the scope, counter, and step attenuator. Adjust the output level so that both the scope sync and the counter operate satisfactorily. Connect the output of the step attenuator to the two IF modules in parallel and insert the two scope probes of the dual channel scope into the banana jack test points of the last IF stage. Adjust the step attenuator so that the signal output level into the scope is no more than 5 volts peak to peak and adjust the input adder pots so that the output level is the same with the input connected to either side of the adder.

For an initial adjustment, set the IF gains wide open, adjust the first three coupling condensers for minimum coupling, and the last one for maximum, and peak each stage to 3 mc. Note that since there are two coupled transformers per stage, the peak which is sought is the maximum peak which may be obtained by going back and forth between the two transformers. After the initial tuning has been completed, adjust the IF gain of the higher gain module so that the dc output of the two modules at the center of the band pass are equal. Because of slight differences in circuit components, it will be found that this adjustment will give rise to slightly different amplitudes at the banana jack test points. It will, therefore, be necessary to adjust the gain of one scope channel so that the apparent amplitude of the two channels are equal.

If all of the adjustments have been made properly, it will be found that the 3 mc sine wave output from the two channels will coincide over the entire band pass. If the two signals do not coincide, slight adjustments in coupling or tuning and gain will bring the two channels into coincidence. This last step is very much a "cut and try" process and it was found that slight adjustment of only the first or the second stage was sufficient to obtain satisfactory results.

4.3 Alignment of the Mixer Module

With the IF strips properly aligned the adjustment of the mixer module is relatively simple. Connect each mixer module to an IF strip and connect the two scope probes to the banana jacks on the IF strip. Feeding a balanced 3 mc signal into each mixer module, peak the two IF cans and, if necessary, make slight adjustments so that the two signals will track in the pass band. For this preliminary adjustment turn the balancing potentiometer to half range, the phase adjustment potentiometer fully clockwise and gain potentiometer to wide open. Using the gain and phase potentiometers adjust the two modules for equal signal level and a 45° phase displacement. If previous adjustments have been properly made, it will be found that equal amplitude and the 45° phase displacement will persist all across the pass band.

4.4 Final Adjustments on the Receiver

With the individual modules adjusted as described above, connect the receiver as shown in Figures 1 and 2, leaving out, for the moment, the cross connections between the mixer and the IF modules, and the connections from IF modules to the video amplifier. With the local oscillator set slightly above 3 mc (about 3.05 mc) adjust the balance potentiometers in the cathodes of the 12AX7's in the mixer modules for the minimum dc output from the IF strip. This should be very nearly at the mid range of the potentiometer.

Next insert a 300 kc balanced signal into the RF modules (use parallel connection) and insert the scope probes into the banana jacks on the IF strips. With the local oscillator set at 3.3 mc, adjust the level of the 300 kc signal so that the scope input is less than 5 volts. Using one of the channels for "external sync" on the scope the 3 mc signals which are observed should be of equal amplitude and displaced 45° in phase. A slight adjustment in amplitude may be required to compensate for a possible difference in the gain of the RF modules. This should be taken care of by adjusting the gain of the mixer module, of which the gain has been turned down in the course of the preceding adjustment. Any serious discrepancy in amplitude or 45° phase shift would indicate a malfunction or a misalignment of some stage and should be investigated.

To complete the check out, the above procedure should be repeated at several frequencies between 100 and 1000 kc. In each case, equal amplitudes and a 45° phase shift should be observed in the pass band.

To facilitate the final check a special signal generator has been constructed the output of which consists of two equal 90° phase displaced balanced RF signals, the correct local oscillator frequency and an auxiliary 3 mc "external sync" signal. If this generator is used it will be observed that, upon completing the cross connections between the mixer and the IF modules, the signal level in one channel will double and that in the other will drop to zero. Upon changing the sense of the 90° phase shift at the signal, (by flipping reversing switches) the output levels of the two IF modules are reversed. The final adjustment is completed by connecting the video amplifier and adjusting the output level for proper modulation of the light intensity on the face of the recording scope.

5. Remarks Regarding the Present Receiver

In the course of development of experimental equipment, it is usually found that if the job were done again, certain changes would be incorporated. The present equipment is no exception and for the benefit of those who may wish to duplicate this equipment a few suggestions are hereby made.

The RF module works very well, but its gain is only about 10. It may, therefore, be useful, especially in the area where atmospheric noise is low, to terminate the filter in another RF stage and not in the mixer. If this is done, a gain and balancing potentiometer should be incorporated to make the modules less dependent on tube characteristics.

In the construction of the mixer module, attempts were made to use commercially available parts. Since it was not possible to obtain commercially, a well-balanced split winding 3 mc IF transformer with low impedance output, capacitive division was used. It is felt that better performance would have been obtained if "home made" 3 mc transformers were built using suitable ferrite toroids. It also would have been easier to obtain a lower impedance output and thus make the phase adjustment more nearly independent of amplitude. The loss of gain by going into a lower impedance could have been made up by utilization of a pentode-triode tube such as 6AZ8 instead of the 12AX7.

The IF module is found to work very well. One possible improvement might be to utilize a cathode follower in the d.c. output circuit to lower its impedance. Also, the test point output of the IF signal has been found very useful, but somewhat inconvenient to use because of its relatively low level and high impedance. It is recommended that a high level low impedance IF output be made available.

The video amplifiers worked out very satisfactorily.

The dc amplifier feature greatly facilitates receiver adjustments. No additional recommendations regarding this unit can be made since the specifications for the video amplifier must be tailored to the requirements of the recording system. The present system is capable of providing ±20 volt linear output into a moderately high impedance on the order of 5000 ohms.

Acknowledgments

We wish to express our gratitude to the various members of the IRL staff for their valuable assistance. In particular we wish to thank Mr. M. Horowitz for his assistance in building the receiving equipment and Mr. H. Bonney for the construction of the special calibrating equipment which greatly facilitated calibration and adjustment of the polarization receiver.

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